[Claims]

[Claim 1]

A manufacturing method, for an electron source substrate wherein a plurality of electron emitting devices, including one pair of device electrodes, are arranged on a substrate at positions whereat a plurality of scanning lines and a plurality of signal lines intersect each other, characterized by comprising:

1) a step of forming a plurality of device electrode pairs on said substrate;

2) a step of forming wiring for a first layer including a connector to be attached to one of the device electrodes (a first device electrode) in each of the device electrode pairs;

3) a step of forming an insulating layer having a belt-shaped pattern in which is a recessed portion in a segment that intersects the other device electrode (ac second electrode device) opposite said first device electrode, and forming, on said belt-shaped insulating layer, wiring for a second layer having a width equal to or smaller than the width of said insulating layer, and that contacts said second device electrode in said recessed portion;

4) step of forming a connection layer for connecting said wiring for said second layer and said second device electrode;

5) step of forming wiring for a third layer on

said wiring for said second layer; and

6) step of forming an electron emitting device based on said device pairs.

[Claim 2]

A manufacturing method according to claim 1, whereby said wiring for said second layer and said wiring for said third layer are formed of the same material.

[Claim 3]

A manufacturing method according to claim 1 or 2, whereby said electron emitting devices are provided by forming a conductive thin film between said device pair, and by forming electron emitting portions on one part of said thin film through an electrification process, so that surface-conductive electron emitting devices are formed.

[Claim 4]

A manufacturing method according to one of claims 1 to 3, whereby said wiring for said second layer and a connection layer, which connects said wiring for said second layer to said device electrodes, are formed at the same time.

[Claim 5]

A manufacturing method according to one of claims 1 to 4, whereby a printing method is employed to form said individual layers.

[Claim 6]

A manufacturing method, for an electron source substrate wherein electron emitting devices are arranged

between wiring lines, having a strip shape, formed on a substrate, characterized by comprising:

1) a step of forming a plurality of device electrode pairs on said substrate;

2) a step of forming wiring for a first layer having a connection layer to be connected to one of said device electrodes (first device electrode) for each of said device electrode pairs;

3) a step of forming wiring, for a second layer, running parallel to said wiring for said first layer with said device electrode pairs in between;

4) a step of forming a connection layer for connecting the other device electrode (a second device electrode), opposing said first device electrode, to said wiring for said second layer;

5) a step of forming wiring for a third layer on said wiring for said second layer; and

6) a step of forming an electrode emitting portion based on said device pairs.

[Claim 7]

A manufacturing method according to claim 6, whereby said wiring for said second layer and said wiring for said third layer are formed of the same material.

[Claim 8]

A manufacturing method according to claim 6 or 7, whereby said electron emitting devices are provided by forming a conductive thin film between said device pair,

and by forming electron emitting portions on one part of said thin film through an electrification process, so that surface-conductive electron emitting devices are formed.

[Claim 9]

A manufacturing method, for an electron source substrate, according to one of claims 6 to 8, whereby said wiring for said second layer and a connection layer, which connects said wiring for said second layer to said device electrodes, are formed at the same time.

[Claim 10]

A manufacturing method, for an electron source substrate, according to one of claims 6 to 9, whereby a printing method is employed to form said individual layers.

[Claim 11]

A manufacturing method, for an image forming apparatus, comprising the steps of:

arranging, opposite each other, an electron source substrate, obtained by a method according to one of claims 6 to 10, and a substrate including an image formation area, and bonding said two substrates through a support frame, while arranging a plurality of third electrodes between said two substrates;

reducing pressure in a space defined between said two substrates; and

connecting a drive circuit, used for image formation, to said electron source substrate and said grid electrodes.

[Claim 13]

An electron source substrate manufactured by a method according to one of claims 1 to 10.

[Claim 14]

An image forming apparatus manufactured by a method according to claim 11 or 12.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to an electron source and an image forming apparatus, such as a display device, that employs the electron source.

[0002]

[Prior Art]

Conventionally, there are two types of electron emitting devices: a thermionic source and a cold cathode electron source. As the cold cathode electron source, there are electron emitting devices of a field emission type (hereinafter referred to as an FE), metal/insulating layer/metal type (hereinafter referred to as an MIM) and a surface-conductive electron type.

[0003]

As example FE types, well known electron emitting devices are described in the report by Dyke ("Field emission", W. P. Dyke and W. W. Dolan, Advance in Electron Physics, 8, 89 (1956)) and in the report by Spindt ("Physical Properties of thin-film field emission cathodes

with molybdenium cones", C. A. Spindt, J. Appl. Phys., 47, 5248 (1976)).

[0004]

As an example MIM type, a well known electron emitting device is described in the report by Mead ("The tunnel-emission amplifier", C. A. Mead, J. Appl. Phys., 32, 646 (1961)).

[0005]

As an example surface-conductive type, a well known electron emitting device is described in the report by Elinson (M. I. Elinson, Radio Eng. Electron Phys., 10 (1965)).

[0006]

When a current flows parallel to the face of a thin film that is formed within a small space on a substrate, an electron emission phenomenon occurs. The surface-conductive electron emitting device employs this phenomenon.

[0007]

As the surface-conductive electron emitting device, there are reports covering an electron emitting device that employs a SnO_2 thin film described in the report by Elinson, an electron emitting device that employs an Au thin film ("Thin solid Films", G. Dittmer, 9, 317 (1972)), an electron emitting device that employs an In_2O_3/SnO_2 thin film ("IEEE Trans. ED Conf.", M. Hartwell and C. G. Fonstad, 519 (1975)), and an electron emitting device that employs a

carbon thin film ("Vacuum", Araki, et. al., Vol. 26, No. 1, p. 22 (1983)).

[0008]

As a typical device structure for these surface-conductive electron emitting devices, the structure of the device provided by Hartwell is shown in Fig. 6. In Fig. 6, reference numeral 1 denotes a substrate. Reference numeral 2 denotes a thin film, which is used to form an electron emitting portion, and is, for example, a metal oxide thin film, having an H shape, formed by sputtering. An electron emitting portion 3 is formed by an electrification process called electroforming, which will be described later. It should be noted that in Fig. 6 a device electrode interval L1 is set to 0.5 to 1.0 mm, and W' is set as 0.1 mm. Since the position and the shape of the electron emitting portion 3 are unknown, the electron emitting portion 3 is depicted as a specific example.

[0009]

Conventionally, for these surface-conductive electron emitting devices, in general, before electrons are emitted, an electrification process called electroforming is performed for a thin film, for forming the electron emitting portion, and the electron emitting portion 3 is formed. That is, during the electroforming, a direct-current voltage, or a very slowly increasing voltage, of about 1 V/min, is applied to both ends of the thin film 2 for forming an electron emitting portion, and the

conductive thin film is locally destroyed, deformed or altered to produce the electron emitting portion 3 in an electrical, highly resistant state. It should be noted that, as the electron emitting portion 3, a crack occurs in a part of the thin film 2 for forming an electron emitting portion, and electrons are emitted from near the crack. Hereinafter, a thin film for forming an electron emitting portion, including electron emitting portions that are generated by electroforming, is called a thin film (4 in Fig. 6) that includes electron emitting portions. In the surface-conductive electron emitting device provided by the electroforming process, when a voltage is applied to the thin film 4 that includes electron emitting portions, and when a current is supplied to the surface of the device, electrons are emitted by the electron emitting portion 3.

[0010]

Generally, use of a procedure called "activation" is initiated after the electroforming procedure is terminated. The objective of this procedure is to increase the number of electrons emitted by applying a constant voltage, over a constant period of time, to the surface-conductive electron emitting device for which the resistance is increased by electroforming.

[0011]

Since the above described surface-conductive electron emitting device has a simple structure and is easily manufactured, it provides an advantage in that

multiple surface-conductive electron emitting devices can be arranged across a large area. Thus, various applications have been studied to determine the best use of this characteristic. For example, the practical use of a charged beam source and a display device for an image forming apparatus has been studied.

[0012]

[Problems to be solved by the Invention]

However, the following problems have arisen when there is an increase in the size of the above described surface-conductive electron emitting device to be used for an image forming apparatus. When an electrode and a writing pattern are processed during the process for manufacturing the surface-conductive electron emitting device, an electrode and a metal thin film, as wiring material, are deposited on a substrate and are processed by a common photolithography and a common etching technique, and an electrode and a wiring pattern are obtained. However, when a large substrate, of 40 square cm or more, is employed to deposit the electrode and the wiring pattern using the photolithography and the etching technique, a large manufacturing facility, including an evaporation apparatus, an exposure apparatus and an etching apparatus, and a huge monetary expenditure are required. Further, when the size of a substrate is to be increased, it is difficult to increase the overall size of the manufacturing apparatus, and a problem exists that affects the

manufacturing method and the manufacturing costs. In addition, since the number of electrodes and the number of circuits are increased, and the circuits become increasingly complicated as their sizes are expanded, there are problems in that, for example, the number of procedures is increased, defects, such as disconnections a short-circuits, tend to occur, and yields are reduced.

[0013]

To resolve these conventional shortcomings, one objective of the present invention is to provide a method for manufacturing an electron source wherein a plurality of surface-conductive electron emitting devices are arranged, and an image forming apparatus whereby the manufacturing costs and the number of procedures are reduced, the structure of an electrode and a wiring portion is simplified, so that the reliability of mutual electrical connected portions is improved, and an image having a higher quality can be obtained by using a high-density pixel array.

[0014]

[Means for Solving the Problems]

According to the present invention, provided is a manufacturing method, for an electron source substrate wherein a plurality of electron emitting devices, including one pair of device electrodes, are arranged on a substrate at positions whereat a plurality of scanning lines and a plurality of signal lines intersect each other,

characterized by comprising:

1) a step of forming a plurality of device electrode pairs on the substrate;

2) a step of forming wiring for a first layer including a connector to be attached to one of the device electrodes (a first device electrode) in each of the device electrode pairs;

3) a step of forming an insulating layer having a belt-shaped pattern in which is a recessed portion in a segment that intersects the other device electrode (ac second electrode device) opposite the first device electrode, and forming, on the belt-shaped insulating layer, wiring for a second layer having a width equal to or smaller than the width of the insulating layer, and that contacts the second device electrode in the recessed portion;

4) step of forming a connection layer for connecting the wiring for the second layer and the second device electrode;

5) step of forming wiring for a third layer on the wiring for the second layer; and

6) step of forming an electron emitting device based on the device pairs. Furthermore, a manufacturing method is provided for an image processing apparatus, comprising:

a step of locating an electron source substrate, manufactured using the above method, and a substrate,

having an area for forming an image, facing each other, and bonding the electron source substrate and the substrate through a support frame;

a step of reducing pressure in a space between the two substrates; and

a step of connecting, to the electron source substrate, a drive circuit for image forming.

[0015]

Further, according to the present invention, provided is a manufacturing method, for an electron source substrate wherein electron emitting devices are arranged between wiring lines, having a strip shape, formed on a substrate, characterized by comprising:

1) a step of forming a plurality of device electrode pairs on the substrate;

2) a step of forming wiring for a first layer having a connection layer to be connected to one of the device electrodes (first device electrode) for each of the device electrode pairs;

3) a step of forming wiring, for a second layer, running parallel to the wiring for the first layer with the device electrode pairs in between;

4) a step of forming a connection layer for connecting the other device electrode (a second device electrode), opposing the first device electrode, to the wiring for the second layer;

5) a step of forming wiring for a third layer on

the wiring for the second layer; and

6) a step of forming an electrode emitting portion based on the device pairs. Furthermore, a method is provided for manufacturing an image forming apparatus, comprising:

a step of arranging an electron source substrate, manufactured using the above described method, and a substrate including an area, for forming an image, facing each other, and of bonding the two substrates through a support frame, while a plurality of grid electrodes are arranged between the two substrates;

a step of reducing pressure in a space defined between the two substrates; and

a step of connecting, to the electron source substrate and the grid electrodes, a drive circuit for image forming.

[0016]

When the manufacturing method of the present invention is compared with the conventional method, with a simple structure wherein a wiring structure of double layers is employed,

1) the reliability of portions whereat an electrode and wiring are connected can be improved;

2) the wiring resistance can be reduced;

3) the occurrence of uneven pixels, due to an increase in the wiring resistance, which used to be a problem for increasing the size, can be prevented; and

4) a high-definition image forming apparatus having a large screen can be obtained.

[0017]

[Modes for carrying out the Invention]

The present invention will now be described in detail while referring to the drawings.

[0018]

In Fig. 1 is shown a typical device structure for an electron source substrate manufactured using a method according to the present invention. Fig. 1(a) is a plan view and Fig. 1(b) is a partially cut away plan view.

[0019]

The processing of the manufacturing method according to the invention are shown in Figs. 2 and 3. Fig. 2 is a step diagram showing the first half of the processing, and Fig. 3 is a step diagram showing the second half of the processing. In Figs. 2 and 3, as an example, a total of nine electron emitting devices are arranged in a 3 x 3 matrix on a substrate (not shown), together with wiring. In Figs. 2 and 3, reference numerals 11 and 12 denote a pair of device electrodes; 13, wiring for a first layer; 14, an inter-layer insulating layer located between the wiring for the first layer and the wiring for the second layer; 15, wiring for the second layer; 16, wiring for the third layer; and 17, a film for forming an electron emitting portion.

[0020]

The electron source substrate manufacturing method will now be described in detail while referring to Figs. 2 and 3.

[0021]

First, device electrodes are printed and annealed on a substrate that has been rinsed in advance, and a device electrode pair of the device electrodes 11 and 12 is formed (Fig. 2(a)). These electrodes are provided to obtain a satisfactory ohmic contact between the electron emitting, portion forming thin film and the wiring. Generally, the thin film for forming an electron emitting portion is considerably thinner than a conductive layer for wiring, the electrodes are formed in order to avoid problems, such as "wetting" and "step retentivity". Therefore, when a conductive layer for wiring is formed as a thin film, for example, using the sputtering method, a thin film for forming an electron emitting portion is not always separately deposited, and can be formed together with a wiring conductor.

[0022]

To form the electrodes, available are vacuum methods, such as a vacuum evaporation method, a sputtering method and a plasma CVD method, and a thick film printing method, for printing and annealing a thick film paste that is prepared by mixing a metal element and a glass element in a catalyst.

[0023]

According to the manufacturing method of the invention, the reduction of the procedures is most remarkable when the thick film printing method that does not require the photolithographic process is employed. However, it is preferable that the thickness of a film be limited for an electrode near an electron emitting portion. Therefore, when the thick film printing method is employed, it is preferable that an MOD paste that contains an organic metal compound be used. Of course, another film deposition method may be employed, and the constituent material is not especially limited so long as the material is electrically conductive.

[0024]

Next, the wiring 13 for the first layer is formed (Fig. 2(b)). The wiring can be formed by using the same method as used for the device electrodes 11 and 12, and unlike the electrode portion, it is advantageous for the film for the wiring to be thick, because electrical resistance can be reduced. Therefore, the thick film printing method is effective. Naturally, thin film wiring can also be employed; however, since it takes time to increase the thickness, the use of the thin film wiring is not preferable.

[0025]

Following this, the inter-layer insulating film 14 is deposited (Fig. 2(c)). The inter-layer insulating film is shaped like a belt, and recessed portions 14a are formed

at the intersections with the device electrodes 12, so that the device electrodes 12 are exposed at the recessed portions 14a. As is apparent from Fig. 1, the width of the inter-layer insulating film is set so it is greater than the width of the wiring for the second layer at the next step. This is because a it prevents a short-circuit at the intersection of the wiring for the first layer and the wiring for the second layer. The insulating layer need only be made of an insulating material, and can, for example, be an SiO_2 thin film, or a film made of a thick film paste that does not contain a metal element.

[0026]

Then, the wiring 15 for the second layer is formed (Fig. 3(d)). In this case, formation of the wiring 15 for the second layer and the connection of the wiring for the second layer to the device electrodes 11 are performed at the same time. For forming the wiring 15, the same method as that used for the wiring for the first layer can be employed. According to this method, since the device electrodes are connected at the recessed portions 14a of the inter-layer insulating film at the same time as the wiring for the second layer is formed, a connection pattern need not be provided, and the number of processes can be reduced.

[0027]

Next, the wiring 16 for the third layer, which is the feature of the invention, is deposited (Fig. 3(e)).

For the formation of the wiring for the third layer, the wiring for the second layer is formed, and the process is repeated by using the same material as used for the wiring for the second layer and under the same conditions. When the wiring for the third layer is thus formed, a defect portion, such as "crack" or a "cut", in the portion wherein the wiring for the second layer contacts the device element, can be covered with the wiring for the third layer that has been printed, and a good contact can be obtained. Further, since the thickness of the wiring layer is doubled, low-resistant wiring can be obtained.

[0028]

Finally, the film 17 for an electron emitting portion is formed so that electron emitting devices (3 x 3, i.e., a total of nine) for an electron source can be completed (Fig. 3(f)). For film formation and formation of the electron emitting portions 17 (surface-conductive electron emitting devices), the conventional methods can be employed unchanged (that will be described later).

[0029]

In Figs. 2 and 3, only a portion composed of nine devices is shown. When a plurality of the portions are formed at the same time, an electron source having a simple matrix structure can be provided.

[0030]

The present invention provides superior effects for an image forming apparatus of a simple matrix type that

employs a surface-conductive electron emitting device, and also provides superior effects for a manufacturing method for an image forming apparatus that uses using the thick film printing method.

[0031]

A schematic explanation will be given for the basic structure of a surface-conductive electron emitting device according to the present invention, a manufacturing method therefor, and a feature therefor (by referring, for example, to Japanese Patent Laid-Open Publication No. Hei 2-56822).

[0032]

For the surface-conductive electron emitting device according to the present invention,

1) a thin film, which is used for forming an electron emitting portion and is obtained before an electrification process called electroforming is employed, is basically formed of particulates, and is, for example, a thin film made of particulates obtained by dispersing a particulate dispersive body, or a thick film made of particulates that are obtained by heating and annealing, for example, an organic metal; and

2) a thin film, which includes an electron emitting portion and is obtained after the electrification process called electroforming, is basically made of particulates, as is the electron emitting portion.

[0033]

Figs. 7(a) and (b) are a plan view and a cross-sectional view of the structure of the basic surface-conductive electron emitting device according to the present invention. The basic structure of the device of the invention will be described while referring to Fig. 7. For an electron source and an image forming apparatus according to the invention, as will be described later, multiple surface-conductive electron emitting devices are arranged on a single substrate, together with wiring electrodes.

[0034]

In Fig. 7, reference numeral 1 denotes an insulating substrate; 5 and 6, device electrodes; 4, a thin film, including electron emitting portions; and 3, an electron emitting portion.

[0035]

The insulating substrate 1 can be silica glass, glass containing a reduced content of an impurity such as Na, blue plate glass, a glass substrate obtained by laminating SiO_2 (an insulating layer) on blue plate glass, for example, using the sputtering method, or ceramics such as alumina. A general conductor is employed as the material for the opposed device electrodes 5 and 6, and can, for example, be a metal such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu, Pd, Ag, Ru, Ta, Pb, Zr, Hf, Sb or La; an alloy of one of these metals; a metal such as Pd, Ag, Au, RuO_2 or Pd-Ag; a printing conductor formed of a metal oxide and

glass; a transparent conductor such as In_2O_3-SnO_2; or a semiconductor material such as polysilicon.

[0036]

A device electrode interval L1 is several Å to several hundreds of μm, and is set in accordance with the photolithography technique, which is the base of the device electrode manufacturing method, i.e., the exposure apparatus function and the etching method, a voltage applied between the device electrodes and the field intensity at which electrons can be emitted. Preferably, the device electrode interval L1 is several μm to several tens of μm. A device electrode length W1 and a film thickness d, for the device electrodes 5 and 6 that are appropriately designed in accordance with the resistance of the electrode, the connection of X and Y wiring lines that will be described later, and matter concerning the arrangement of multiple electron sources. Generally, the device electrode length W1 is several μm to several hundreds of μm, and the film thickness d for the device electrodes 5 and 6 is several hundreds of Å to several thousands of Å.

[0037]

The thin film 4, including electron emitting portions, is deposited between the opposing device electrodes 5 and 6, which are formed on the insulating substrate 1, and on the device electrode pair 5 and 6. The thin film 4 includes the electron emitting portion 3, and

not only as is shown in the case in Fig. 7(b), the thin film 4 may not be deposited on the device electrodes 5 and 6. That is, on the insulating substrate 1, the thin film for forming an electron emitting portion and the pair of opposing device electrodes 5 and 6 may be laminated in the named order. Furthermore, depending on the manufacturing method, the portion between the opposing device electrodes 5 and 6 may function as an electron emitting portion. The thickness of the thin film, including electron emitting portions, is several of Å to several thousands of Å, and is appropriately designed in accordance with the step coverage to the device electrodes 5 and 6, the resistance between the electron emitting portion 3 and the device electrodes 5 and 6, and the size of the conductive particulates of the electron emitting portion 3, and an electrification process condition that will be described later. The resistance of the thin film 4 is a sheet resistance of 10^3 to 10^7 Ω/□.

[0038]

The material for forming the thin film 4, including electron emitting portions, can be, for example, a metal such as Pd, Pt, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W or Pb; an oxide such as PdO, SnO_2, In_2O_3, PbO or Sb_2O_3; a boride such as HfB_2, ZrB_2, LaB_6, CeB_6, YB_4 or GdB_4; a carbide such as TiC, ZrC, HfC, TaC, SiC or WC; a nitride such as TiN, ZrN or HfN; a semiconductor such as Si or Ge; or carbon.

[0039]

A particulate film described here is a film formed of a set of a plurality of particulates, and the microstructure of this film indicates not only a film wherein individual particulates are dispersed and arranged, but also a film wherein particulates are arranged adjacent to each other or overlapped (including an island-shaped state). The size of the particulate is several of Å to several thousands of Å, preferably, 10 Å to 200 Å.

[0040]

The electron emitting portion 3 is a highly resistant crack that is formed, for example, by electroforming, in a part of the thin film 4 that includes electron emitting portions. Further, conductive particulates having a size of several of Å to several hundreds of Å may be included in the crack. The conductive particulates contain at least a part of the elements of a material that forms the thin film 4, including electron emitting portions. The electron emitting portion 3 and the thin film 4, including electron emitting portions, may contain carbon or a carbon compound.

[0041]

Various methods can be employed for manufacturing an electron emitting device that includes the electron emitting portion 3, and an example method is shown in Fig. 8. Reference numeral 2 denotes a thin film for forming an electron emitting portion, and a particulate film is an example thin film.

[0042]

The device manufacturing method will now be described in due order while referring to Figs. 7 and 8.

[0043]

1) The insulating substrate 1 is adequately cleaned by using a cleaner, pure water and an organic solvent, and a device electrode material is deposited on the insulating substrate 1 by vacuum evaporation or sputtering, for example. Thereafter, using the photolithography technique, the device electrodes 5 and 6 are formed on the face of the insulating substrate 1 (Fig. 8(a)).

[0044]

2) An organic metal solution is coated between the device electrodes 5 and 6 on the insulating substrate 1, and the resultant structure is left for a while to form an organic metal thin film. The organic metal solution used here is a solution of an organic compound that employs, as an element, the above described metal such as Pd, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W or Pb. Then, the organic metal thin film is heated and annealed, and is patterned, for example, by lift-off or etching, and the thin film 2 for forming an electron emitting portion is obtained (Fig. 8(b)).

[0045]

The method used for coating the organic metal has been explained. However, the method is not limited to this,

and a vacuum evaporation method, a sputtering method, a chemical vapor evaporation method, a dispersion coating method, a dipping method or a spinner method may be employed for the formation.

[0046]

3) Sequentially, an electrification process called electroforming is performed. During the electroforming, the device electrodes 5 and 6 are electrified by a power source (not shown) to locally destroy, deform or alter the thin film 2 to form an electron emitting portion, so that the portion wherein the structure is changed is obtained. The portion wherein the structure is locally changed is called the electron emitting portion 3 (Fig. 8(c)). As previously described, the present inventor observed that the electron emitting portion 3 is formed of conductive particulates.

[0047]

An example voltage waveform used in the above described electroforming process is shown in Fig. 9.

[0048]

A voltage waveform having a pulse shape is particularly preferable, and there is a case (Fig. 9(a)) wherein a voltage pulse having a constant pulse peak value is sequentially applied, and a case (fig. 9(b)) wherein a voltage pulse is applied while the pulse peak value is increased. First, the case (Fig. 9(a)) wherein a voltage having a constant pulse peak value is applied will be

explained.

[0049]

In Fig. 9(a), T1 and T2 denote a pulse width and a pulse interval for a voltage waveform. T1 is set as 1 μ seconds to 10 milliseconds, while T2 is set as 10 μ seconds to 100 milliseconds, and the peak value of a triangular wave (the peak voltage in the electroforming process) is appropriately selected in accordance with the form of the surface-conductive electron emitting device. This voltage wave is applied for several seconds to several tens of seconds in a vacuum ambience of an appropriate vacuum level, for example, 1 to 10^{-5} Torr. The wave to be applied to the device electrodes need not be limited to a triangular wave, and a desired wave, such as a rectangular wave, may be employed. Further, the peak value, the pulse width and the pulse interval are also not limited to the above described values, and desired values can be selected so long as an electron emitting portion is adequately formed.

[0050]

In Fig. 9(b), T1 and T2 are the same as in Fig. 9(a), and the peak value (the peak voltage in the electroforming process) of a triangular wave is applied in an appropriate vacuum ambience while it is increased in steps, for example, of about 0.1 V.

[0051]

During the electroforming process in this case, at a pulse interval T2, a device current is measured by

applying a voltage, for example, of about 0.1 V that does not locally destroy or deform the thin film 2, for forming an electron emitting portion, and a resistance is obtained. When, for example, the resistance becomes equal to or greater than 1 MΩ, the electroforming process is terminated.

[0052]

It is preferable that a process called an activation step be performed next for a device for which the electroforming process has been performed.

[0053]

The activation step is a process during which, as in the electroforming process, a voltage pulse having a constant pulse peak value is repetitively applied at a vacuum level of about 10^{-4} to 10^{-5} Torr, and in which carbon or a carbon compound, derived from an organic material, that is present in a vacuum is deposited on the thin film to considerably change a device current If and a discharge current Ie. When the device current If and the discharge current Ie are measured, and when, for example, the discharge current Ie is saturated, the activation step is terminated. Further, it is preferable that an operation drive voltage be employed as the voltage pulse to be applied.

[0054]

The carbon or the carbon compound in this case is graphite (both single crystal and polycrystal) or amorphous

carbon (a mixture of amorphous carbon and polycrystalline graphite), and the thickness thereof is preferably 50 Å or smaller, and preferably 300 Å or smaller.

[0055]

The thus manufactured electron emitting device should be driven under a vacuum ambience that is higher than a vacuum level for the electroforming step and the activation step. Further, it is preferable that the electron emitting device that has been heated at 80°C to 150°C be driven under an ambience at a higher vacuum level.

[0056]

A vacuum level higher than the vacuum level for the electroforming step and the activation step is, for example, a vacuum level of about 10^{-6} Torr, and more preferably an ultrahigh vacuum level at which additional carbon or a carbon compound is almost not deposited on the conductive thin film. Through this processing, the device current If and the discharge current Ie can be stabilized.

[0057]

While referring to Figs. 10 and 11, an explanation will now be given for the basic characteristics of the electron emitting device of the invention, which has the above described device structure and which is obtained using the manufacturing method.

[0058]

Fig. 10 is a schematic diagram showing the configuration of a measurement and evaluation apparatus for

measuring the electron emission characteristics of the device having the structure in Fig. 7. In Fig. 10, reference numeral 1 denotes an insulating substrate; 5 and 6, device electrodes; 4, a thin film, including electron emitting portions; and 3, an electron emitting portion. Furthermore, reference numeral 91 denotes a power source for applying a device voltage Vf to the device; 90, an ammeter for measuring the device current If that flows across the thin film 4, that includes an electron emitting portion and that is located between the device electrodes 5 and 6; 94, an anode electrode for capturing the discharge current Ie that is discharged by the electron emitting portion of the device; 93, a high voltage power source for applying a voltage to the anode electrode 94; and 92, an ammeter for measuring the discharge current Ie that is discharged by the electron emitting portion 3 of the device. For the measurement of the device current If and the discharge current Ie of the electron emitting device, the power source 91 and the ammeter 90 are connected to the device electrodes 5 and 6, while the high voltage power source 93 and the ammeter 92 are connected to the anode electrode 94, which is located above the electron emitting device. The electron emitting device and the anode electrode 94 are arranged in a vacuum apparatus wherein devices, such as an exhaust pump and a vacuum gage, required for the vacuum apparatus, are provided, so that the measurement and the evaluation of the device can be

performed under a desired vacuum. It should be noted that measurement was performed at a voltage for the anode electrode of 1 to 10 kV, and at a distance, H of 3 to 8 mm, between the anode electrode and the electron emitting device.

[0059]

In Fig. 11 is shown a typical example for a relationship of the discharge current Ie, the device current If and the device voltage Vf, which were measured by the measurement and evaluation apparatus shown in Fig. 10. In Fig. 11, an arbitrary unit is employed, and the discharge current Ie is about one thousandth of the device current If. As is apparent from the graph, the electron emitting device has three characteristics relative to the discharge current Ie.

[0060]

First, when a specific device voltage (called a threshold voltage; Vth in Fig. 11) or higher is applied to the electron emitting device, the discharge current Ie is sharply increased. On the other hand, when a voltage lower than the threshold voltage is applied, almost no discharge current Ie is detected. That is, the electron emitting device is a non-linear device that has the clear threshold value Vth relative to the discharge current Ie.

[0061]

Second, since the discharge current Ie depends on the device voltage Vf, the discharge current Ie can be

controlled by using the device voltage Vf.

[0062]

Third, the strength of the charges captured by the anode electrode 94 can be controlled in accordance with the time for applying the device voltage Vf.

[0063]

Since the electron emitting device of the invention has the above described characteristics, the use of the electron emitting device for different fields can be expected. An example characteristic (MI) wherein the device current If is monotonically increased, relative to the device voltage Vf, is shown in Fig. 11. In addition to this example, there is a case wherein the voltage control negative resistance (VCNR) characteristic of the device voltage If appears relative to the device voltage Vf. In this case, the electron emitting device has the three characteristics described above. For manufacturing a surface-conductive electron emitting device by dispersing conductive particulates in advance, the basic manufacturing method for the basic device structure of the invention may be partially altered.

[0064]

Next, an electron source and an image forming apparatus according to the present invention will be described.

[0065]

An electron source substrate used for an image

processing apparatus is obtained by arranging a plurality of surface-conductive electron emitting devices on the substrate. As types of arrangements for the surface-conductive electron emitting devices, there are a ladder arrangement (hereinafter referred to as a ladder arrangement electron source substrate) wherein surface-conductive electron emitting devices are arranged in parallel, and both ends of each device are connected using wiring, and a simple matrix arrangement (hereinafter referred to as a matrix arrangement electron source substrate) wherein X-directional wiring and Y-directional wiring are connected to one pair of device electrodes for each surface-conductive electron emitting device. An image forming apparatus employing the matrix arrangement electron source substrate needs control electrodes (grid electrodes) that are electrodes for controlling the flow of electrons from the electron emitting device.

[0066]

The structure of the electron source substrate provided based on the above principle will now be explained while referring to Fig. 12. Reference numeral 111 denotes an insulating substrate; 112, X-directional wiring lines; 113, Y-directional wiring lines; 114, surface-conductive electron emitting devices; and 115, connection lines. In Fig. 11, the insulating substrate 111 is made, for example, of the glass described above, and the size and the thickness thereof are appropriately designated in

accordance with the number of surface-conductive electron emitting devices and the designed shape of each device, and further, when the electron sources in use constitute a part of a container, in accordance, for example, with a condition for maintaining a vacuum in the container. The m X-directional wiring lines 112 are Dx1, Dx2, . . . and Dxm, and are made, for example, of conductive metal that is patterned to provide a predetermined shape, and the material, the film thickness and the wiring width, for example, are designated in order to apply an almost equal voltage to many surface-conductive electron emitting devices. The Y-directional wiring lines 113 are n wiring lines of Dy1, Dy2, . . . and Dyn. As well as the X-directional wiring lines 112, the Y-directional wiring lines 113 are made, for example, of a conductive metal that is patterned to provide in a desired shape, and the material, the film thickness and the wiring width, for example, are designated in order to apply an almost equal voltage to many surface-conductive electron emitting devices.

[0067]

Since an inter-layer insulating layer (not shown) is provided between the m X-directional wiring lines 112 and the n Y-directional wiring lines 113, these wiring lines are electrically separated and form matrix wiring. It should be noted that m and n are both positive integers. The inter-layer insulating layer (not shown) is made, for

example, of SiO_2, and is formed in a predetermined shape on all or a part of the face of the insulating substrate 111 where the X-directional wiring lines 112 are provided. The film thickness, the material and the manufacturing method for the inter-layer insulating layer are appropriately designated in order, especially, to withstand a potential difference at the intersections of the X-directional wiring lines 112 and the Y-directional wiring lines 113. Further, the X-directional wiring lines 112 and the Y-directional wiring lines 113 are led out as external terminals.

[0068]

The explanation has been given by using an example wherein the n Y-directional wiring lines 113 are located above the m X-directional wiring lines 112 through the inter-layer insulating film. However, the m X-directional wiring lines 112 may be located above the n Y-directional wiring lines 113 through the inter-layer insulating layer.

[0069]

Furthermore, in the same manner as described above, opposing device electrodes (not shown) of the surface-conductive electron emitting devices 114 are electrically connected, by the connection lines 115, to the m X-directional wiring lines 112 Dx1, Dx2, . . . and Dxm and the n Y-directional wiring lines 113 Dy1, Dy2, . . . and Dyn.

[0070]

As for the conductive metal used for the m X-

directional wiring lines 112, the n Y-directional wiring lines 113, the connection lines 115 and the device electrodes, part or all of the elements may be either the same or different, and an appropriate conductive metal is selected, a metal such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu or Pd and alloys of these metals; a metal such as Pd, Ag, Au, RuO_2 or Pd-Ag, and printing conductors formed, for example, of metal oxide and glass; transparent conductors such as In_2O_3-SnO_2; and semiconductor materials such as polysilicon. Furthermore, the surface-conductive electron emitting devices amy be formed on either the insulating substrate 111 or the inter-layer insulating film (not shown).

[0071]

Further, scan signal generation means (not shown) is electrically connected to the X-directional wiring lines 112 in order to transmit a scan signal that is used to scan an arbitrary row of the surface-conductive electron emitting devices arranged in the X direction. While, modulation signal generation means (not shown) is electrically connected to the Y-directional wiring lines 113 to transmit a modulation signal that is used to modulate an arbitrary column of the surface-conductive electron emitting devices 114 arranged in the Y direction.

[0072]

In addition, a drive voltage to be applied to each surface-conductive electron emitting device is transmitted

as a potential difference between the scan signal and the modulation signal to be applied to the pertinent device. According to this configuration, merely by employing simple matrix wiring, the individual devices can be selected and independently driven.

[0073]

While referring to Figs. 4 and 5, an explanation will be given for an image forming apparatus that employs the thus obtained electron source of the simple matrix arrangement. Fig. 4 is diagram showing the basic configuration of the image forming apparatus, and Fig. 5 shows patterns for fluorescent films used by the image forming apparatus.

[0074]

In Fig. 4, reference numeral 31 denotes an electron source substrate on which the electron emitting devices are formed, in the above described manner; 34 corresponds to electron emitting devices; 35 and 36 denote X-directional wiring lines and Y-directional wiring lines connected to one pair of device electrodes of a surface-conductive electron emitting device. Reference numeral 32 denotes a rear plate to which the electron source substrate 31 is fixed; 40, a face plate wherein a fluorescent film 38 and a metal back 39 are formed on the inner face of a glass substrate 37; and 33, a support frame. Frit glass is coated on the rear plate 32, the support frame 33 and the face plate 40, and the resultant structure is sealed by

being annealed in air or in nitrogen at 400 to 500°C for ten minutes or longer. As a result, an outer case 41 is obtained.

[0075]

As is described above, the outer case 41 is constituted by the face plate 40, the support frame 33 and the rear plate 32. Since the rear plate 32 is provided mainly for the reinforcement of the strength of the electron source substrate 31, so long as the electron source substrate 31 has a sufficient strength, the rear plate 32 is not required. In this case, the support frame 33 may be directly attached to the electron source substrate 31, and the outer case 41 may be constituted by the face plate 40, the support frame 33 and the electron source substrate 31. In addition, an atmospheric pressure resistant support member called a spacer may be provided between the face plate 40 and the rear plate 32, so that an outer case 41 can be provided that has sufficient strength relative to an atmospheric pressure.

[0076]

In Fig. 4, reference numeral 38 denotes a fluorescent film. For monochrome, the fluorescent film 38 is made only of a fluophor, and for color, the fluorescent film 38 is made of an arrangement of black members 42 and fluophors 43 that is called black stripes or a black matrix, depending on how the fluophors 43 are arranged. The objective for the forming of the black stripes or the black

matrix is that, for a color display, a color mixture becomes less outstanding by darkening the gaps between the fluophors 43 for the required three primary colors, and that the reduction of the contrast due to external light reflecting on the fluophor film 38 is restricted. The material for the black stripes is not limited to a material that frequently contains graphite, employed as the main element, and any other material can be employed so long as light transmission and light reflection is low.

[0077]

In order to coat the fluophor 43 on the glass substrate 37, a precipitation method or a printing method is employed, regardless of whether monochrome or color.

[0078]

Further, generally, the metal back 39 is formed on the inner face of the fluophor film 38. The object of the metal back 39 is the prevention, for example, of the charging of electrons emitted onto the face plate 40, the improvement of the luminescence by mirror reflection to the face plate 40 of light transmitted from the fluophor 43 to the inner face, the use of the metal back 39 as an electrode for applying an electron beam accelerating voltage, and the protection of the fluophor 43 from damage by a collision of negative ions that are generated in the outer case. For forming the metal back 39, after the fluorescent film 38 has been formed, a smoothing process (normally called filming) is performed for the inner

surface of the fluorescent film 38, and thereafter, Al is deposited by vacuum evaporation. In order to increase the conductivity of the fluorescent film 38, a transparent electrode (not shown) may be provided on the outer face of the fluorescent film 38 on the face plate 40.

[0079]

Since, for color, the individual fluophors must correspond to the electron emitting devices, the fluophors and the electron emitting devices must be appropriately aligned for the sealing described above.

[0080]

By employing an exhaust pipe (not shown), the outer case 41 is set at a vacuum level of about 10^{-7} Torr, and is sealed. Further, in order to maintain the vacuum level in an outer case 41 that has been sealed, a getter process may be performed. During this process, immediately before or after the outer case 41 is sealed, a getter located at a predetermined position (not shown) in the outer case 41 is heated using a resistance heating method, for example, or a high-frequency heating method, and a film is deposited. Generally, the getter contains Ba, for example, as the primary element, and by the absorption of the deposited film, a vacuum level of 1 to 10^{-5} to 1×10^{-7} Torr, for example, is maintained. It should be noted that appropriate steps are designated after the electroforming of the surface-conductive electron emitting device.

[0081]

For the thus obtained image forming apparatus of the invention, a voltage is applied to the individual electron emitting devices, via the external case terminals Dx1 to Dxm and Dy1 to Dyn, to emit electrons, and a voltage of several kV or higher is applied via a high voltage terminal Hv to the metal back 39 or a transparent electrode (not shown) to accelerate the electron beam. Since the electron beam collides with the fluorescent film 38, and since the fluorescent film 38 is excited and emits light, an image can be displayed.

[0082]

The above described configuration is a required overall configuration for the manufacture of a preferable image forming apparatus used for displaying an image. The detailed portions, such as the materials for the individual members, are not limited to the above described contents, and appropriate materials can be selected for the application of the image forming apparatus.

[0083]

Next, while referring to Figs. 13 and 14, an explanation will now be given for the ladder arrangement electron source substrate and an image displaying apparatus employing this electron source substrate.

[0084]

In Fig. 13, reference numeral 120 denotes an electron source substrate; 121, electron emitting devices 121; and 122, common wiring lines connected to the electron

emitting devices. A plurality of the electron emitting devices 121 are arranged in parallel on the substrate 120 in the X direction (these are called device rows). The ladder electron source substrate is obtained by arranging a plurality of device rows on the substrate. When a drive voltage is applied to the common wiring lines between the individual device rows, these device rows can be driven independently. That is, a voltage having an electron emission threshold value or higher need only be applied to a device row that is permitted for the emission of an electron beam, while a voltage having an electron emission threshold value or lower must be applied to a device row for which the emission of an electron beam is inhibited. Furthermore, for the wring lines Dx2 to Dx9 extended between the device rows, the same wiring line may, for example, be employed as Dx2 and Dx3.

[0085]

Fig. 14 is a diagram showing the structure of an image forming apparatus that includes a ladder arrangement electron source. In Fig. 14, reference numeral 130 denotes grid electrodes; 131, through holes for the passage of electrons; 132, external case terminals Dox1, Dox2, . . . and Doxm; 133, external case terminals G1, G2, . . . and Gn, connected to the grid electrodes 130; and 134, an electron source substrate wherefor the same wiring line is employed as is employed for a common wiring line for the individual device rows, as described above. The same reference

numerals in Fig. 13, as used in Fig. 4 denote identical members. A difference from the above described image forming apparatus of a simple matrix arrangement type is that the grid electrodes 130 are located between the electron source substrate 120 and the face plate 40.

[0086]

Since the grid electrodes 130 can modulate electron beams emitted by the surface-conductive electron emitting devices, circular openings 131 are respectively formed in correlation with the devices, so that electron beams can be passed through stripe-like electrodes that are positioned perpendicular to the device rows in the ladder arrangement. The shape of the grid and the location need not always be those shown in Fig. 14. Multiple through holes may be formed in a mesh shape, or the grid may be located on the periphery or in the vicinity of the surface-conductive electron emitting devices. The external case terminals 132 and the external case grid terminals 133 are electrically connected to a control circuit (not shown).

[0087]

For this image forming apparatus, a modulation signal for one line of an image is applied to the grid electrode columns synchronously, as the device rows are sequentially driven (scanned), column by column. Thus, irradiation by the electron beams of the fluophors can be controlled, and an image can be displayed for each line.

[0088]

According to the present invention, an image forming apparatus can be provided that is appropriate not only for a display device for a television program, but also for a display device for a video conference system or a computer. Furthermore, the electron source of the present invention can be employed as an image forming apparatus that functions as an optical printer constituted, for example, by a photosensitive drum.

[0089]

[Embodiments]

The embodiments of the present invention will now be described.

[0090]

(First Embodiment)

In this embodiment, while referring to Figs. 2 and 3, an explanation will be given for the manufacture of an electron source substrate having the configuration shown in Fig. 1, and an image forming apparatus that employs this electron source substrate.

[0091]

First, a pair of device electrodes 11 and 12 were formed on a clean glass substrate (a soda-lime glass substrate was employed in this embodiment). In the embodiment, a thick film printing method was employed as a film deposition method. A thick film paste material used here was an MOD paste, and the metal element was Au.

[0092]

A screen printing method was employed for printing. After printing, the resultant structure was dried at 70°C for ten minutes, and was then annealed in accordance with the embodiment. The annealing temperature was 550°C, and the peak holding period was about eight minutes. The pattern that had been printed and annealed was 350 x 150 μm, and the thickness was about 0.3 μm (Fig. 2(a)).

[0093]

Sequentially, wiring 13 for a first layer was formed and sequentially connected to one side of each device electrode 12. The thick film screen printing method was employed to form the wiring 13 for the first layer. An Ag paste was employed as a thick film paste material, and a metal portion was Ag. When screen printing was performed using a predetermined pattern, the resultant structure was dried at 110°C for twenty minutes and was annealed at 550°C during a peak holding period of fifteen minutes. As a result, the wiring 13, having a width of 100 μm and a thickness of 12 μm, was obtained for the first layer (Fig. 2(b)).

[0094]

Then, an inter-layer insulating film 14 was formed. In this embodiment, this inter-layer insulating film, which had a concave portion (14a in Fig. 1(b)), was formed using the thick film screen printing method. The paste material was a paste mixed with a glass binder containing SiO_x as a main element. The annealing temperature was 550°C and the

peak holding period was about fifteen minutes. When the binder was screen-printed by using a predetermined pattern, and the resultant structure was annealed, a layer having a width of 500 μm and a thickness of about 30 μm was obtained (Fig. 2(c)).

[0095]

Generally, printing and annealing are performed two times each in order to obtain the insulation for the insulating layer between the upper and lower layers. Further, usually a second film that is deposited using the thick film paste is printed and annealed so as to embed the porous portion. As a result, the insulation can be provided. This embodiment followed this process.

[0096]

Next, wiring 15 for a second layer was formed on the insulating layer, so that in the portion, except for the concave portions of the insulating layer, the wiring 15 was narrow and not extended outward from the insulating layer, and the wiring 15 could contact the device electrodes at the concave portions of the insulating layer. The thick film screen printing method was employed for this formation. An Ag paste was employed as a thick film paste material, and the metal portion was Ag. When the resultant structure was screen-printed by using a predetermined pattern and was dried at 110°C for twenty minutes, the obtained structure was annealed at 550°C during a peak holding period of fifteen minutes. As a result, for the

second layer, the wiring 15 having a width of 300 μm and a thickness of 10 μm was obtained (Fig. 3(d)). The wiring 15 for the second layer can be connected directly to the device electrodes 11 by using the concave portions of the insulating layer.

[0097]

Then, wiring 16 for a third layer was formed (Fig. 3(e)), at the same steps and using the same material, at the same location and in the same shape as that of the wiring for the second layer. As a result, the finally obtained wiring layer, formed of the second layer and the third layer, had a width of 300 μm and a thickness of about 20 μm.

[0098]

Through this processing, the matrix wiring portion was completed. Naturally, the paste material and the printing method are not limited to those described above.

[0099]

As for the thus obtained wiring, even when, as in a conventional case, a "crack" or a "cut" occurred in the portion whereat the wiring for the second layer contacts the device electrode, since the wiring for the third layer was printed in the above described manner, such a defect could be covered and a full contact could be obtained. Furthermore, since the thickness of the wiring layer was doubled, low resistant wiring could be provided.

[0100]

After the wiring was completed, electron emitting portions were formed. First, organic palladium (CCP4230; manufactured by Okuno Pharmaceutical Industry Co., Ltd.) was coated, using a spinner, on the layers that were formed using the printing method and that were located on the device electrodes 11 and 12 used for electrifying the electron emitting portions. Then, the resultant structure was heated at 300°C for ten minutes, and a thin film 17 was obtained that formed an electron emitting portion made of Pd. The thus obtained thin film 17, for forming an electron emitting portion, was formed of particulates that employed Pd as a primary element, and the film thickness was 10 nm, while the sheet resistance was $5 \times 10^4\ \Omega/\square$. It should be noted that here the particulate film is a film consisting of a set of a plurality of particulates, and that the microstructure of this film includes not only the state wherein the individual particulates are dispersed and arranged, but also the state (including an island shape) wherein particulates are arranged adjacent each other or overlapped. The size and diameter of the particulate is such that in the above described state the shape of the particulate can be identified.

[0101]

This palladium film was patterned by the photolithography method, and thereafter, before electroforming, the device manufacturing process was completed (Fig. 3 (f)). A conventional method can be

employed as the electroforming method, and in this embodiment, the following conditions were employed (see Fig. 9). In Fig. 9, T1 and T2 denote the pulse width and the pulse interval for a voltage waveform, and in this embodiment, they were respectively set as one millisecond and ten milliseconds. The peak value of a triangular wave (the peak voltage for the electroforming) was 14 V, and the electroforming process was performed for sixty seconds in a vacuum ambience of about 1 x 10^{-6} Torr.

[0102]

The thus manufactured electron emitting portions were in a state wherein particulates containing palladium elements as the primary elements were dispersed, and the average diameter of the particulate was 3 nm.

[0103]

Next, after the electroforming had been performed for all the surface-conductive electron emitting devices, an exhaust pipe (not shown) was heated and welded by a gas burner at a vacuum level of about 1 x 10^{-6} Torr, and the outer case was sealed.

[0104]

Finally, the getter process was performed to maintain the vacuum level in the sealed outer case. During this process, immediately before the sealing, a getter located at a predetermined position (not shown) in the image forming apparatus is heated using a heating method such as a high-frequency heating, and a film is deposited.

The getter contains Ba, for example, as the primary element, and is used to maintain a vacuum level of 1 x 10^{-5} to 1 x 10^{-7} Torr.

[0105]

In the thus obtained image forming apparatus of the present invention, a scan signal and a modulation signal were transmitted, by signal generation means (not shown), to the individual surface-conductive electron emitting devices via the external case terminals Dx1 to Dxm and Dy1 to Dyn. Further, a voltage of several kV or higher was applied to the metal back 39 through a high voltage terminal Hv, and an electron beam was accelerated that collided with the fluorescent film 38. The fluorescent film 38 was in turn excited and emitted light, and an image was displayed. As a result, a satisfactory image having no image defects could be obtained.

[0106]

As is described above, according to the method for this embodiment, since the reliability of the portion whereat the electrodes and wiring are connected is improved, the electron source and the image forming apparatus can be produced that provide a satisfactory yield.

[0107]

Further, according to the method for this embodiment, since the wiring resistance can be reduced, multiple surface-conductive electron emitting devices can be easily arranged in an X-Y matrix shape. Therefore, this

method is appropriate for the manufacture of an image forming apparatus having a large screen.

[0108]

(Second Embodiment)

Next, a ladder electron source substrate having the configuration shown in Fig. 13 was manufactured, and an image forming apparatus shown in Fig. 14 was produced by using this substrate. The manufacturing method therefor will now be described while referring to Figs. 15 and 16.

[0109]

Fig. 15 is a plan view of the structure of a device for the electron source substrate manufactured in this embodiment. Fig. 16 is a step diagram showing the manufacturing processing for the electron source substrate. In an example in Fig. 16, on a substrate (not shown), three electron emitting devices are arranged on a plane, together with a plurality of wiring lines having a strip shape.

[0110]

First, as in the first embodiment, device electrodes 141 and 142 were formed on a clean glass substrate (a soda-line glass substrate was employed in this embodiment). In the embodiment, a thick film printing method was employed as a film deposition method. The thick film paste material used here was an MOD paste, and Pt was employed as a metal portion in this embodiment. The printing method was a screen printing method. After printing, the resultant structure was dried at 70°C for ten

minutes, and was annealed in accordance with the embodiment. The annealing temperature was 550°C, and the peak holding period was about eight minutes. The thickness of the film that was printed and annealed was about 0.25 μm (Fig. 16(a)).

[0111]

Next, line wiring (wiring for a first layer) 143 was formed in a strip shape. At the same time, where the wiring for the first layer was formed, connection patterns (connection layers) 147 and 148 were also formed for the device electrodes 141 and 142. That is, in this case, the material and the conditions used for forming the wiring 143 were also employed for forming the connection patterns 147 and 148, and the thick film screen printing method was employed for the formation. The thick film paste used here was an Ag paste, and Ag was the metal portion. After the screen printing was performed by using a predetermined pattern, the resultant structure was dried at 100°C for twenty minutes, and was annealed at 550°C during a peak holding period of fifteen minutes. As a result, the wiring 143 for the first layer, having a width of 300 μm and a thickness of 10 μm, and the connection patterns for the device electrodes 141 and 142 were obtained (Fig. 16 (b)).

[0112]

Following this, second line wiring (wiring for a second layer) 144 was formed, and wiring 146 for a third layer was overlaid (Fig. 16(c)). To obtain the wiring 146

for the third layer, after the wiring 144 for the second layer was formed, the same wiring as the wiring for the second layer was repetitively overlaid under the same conditions and using the same material composition. Through this process, the finally obtained line wiring layer, formed by the wiring for the second layer, and the wiring for the third layer had a width of 300 μm and a thickness of about 20 μm. Since the thickness of the thus obtained line wiring layer was doubled, the resistance of the wiring could be reduced.

[0113]

Sequentially, electron emitting portions 145 were formed using the same method as in the first embodiment (Fig. 16(d)).

[0114]

Next, as in the first embodiment, the electroforming process was performed for the ladder electron source substrate that included the thus manufactured surface-conducive electron emitting devices.

[0115]

Further, a plurality of these electron sources were placed in a vacuum container, and as in the first embodiment, face plates were arranged opposite each other. As a result, the image forming apparatus was obtained.

[0116]

For the image forming apparatus having the configuration provided in this embodiment, the electron

source substrate is provided wherein devices are arranged along a plurality of strip-shaped wiring lines formed on the plane. Further, a plurality of strip-shaped grid electrodes, which have openings, are positioned on the electron emitting portions of the devices and perpendicular to the wiring lines. Therefore, by controlling the drive voltage that is to be applied to the wiring lines, connected to the electron emitting devices, and the grid electrodes, electrons can be emitted by an arbitrary electron emitting device.

[0117]

According to the method used to manufacture an electron source substrate and an image forming apparatus, the portion whereat the electrodes and the wiring are connected is highly reliable, so that the yield is increased.

[0118]

Furthermore, according to the manufacturing method of the embodiment, since the wiring resistance can be reduced, multiple surface-conductive electron emitting devices can be easily arranged in an X-Y matrix shape, and therefore, this method is appropriate for manufacturing an image forming apparatus having a large screen.

[0119]

In addition, as an application for this invention, an array of light emitting devices is produced by the electron source forming methods described in the first

embodiment and the second embodiment, and is located on a photosensitive drum. As a result, an electrophotographic recording apparatus can be obtained. In this case, the same effects provided by the image forming apparatuses in the first and the second embodiments can also be obtained.

[0120]

[Advantages of the Invention]

As is described above, according to the present invention, for an image forming apparatus employing multiple cold cathode electron beam sources, the portions whereat electrodes and wiring are connected are highly reliable, and an electron source can be formed that includes an electron source substrate wherein thick, low-resistant wiring electrodes are highly accurately formed. Further, it is possible to prevent the occurrence of an uneven image due to an increase in wiring resistance, which is a conventional problem when the screen size of an image forming apparatus, for example, is increased. As a result, a high-definition image forming apparatus can be obtained that has a large screen.

[Brief Description of the Drawings]

[Fig. 1]

This is a specific plan view of a typical device structure for an electron source according to the present invention.

[Fig. 2]

This is a step diagram showing the first half of

example processing for the manufacture of a matrix electron source according to the present invention.

[Fig. 3]

This is a step diagram showing the second half of the example processing for the manufacture of a matrix electron source according to the present invention.

[Fig. 4]

This is a partially cutaway perspective view of the configuration of an example image forming apparatus according to the present invention.

[Fig. 5]

This is a specific partial diagram showing the structure of a fluorescent film, with (a) showing the structure wherefor black stripes are provided, and (b) showing the structure wherefor a black matrix is provided.

[Fig. 6]

This is a schematic plan view of the structure of an example surface-conductive electron emitting deice.

[Fig. 7]

This is a schematic diagram showing the structure of an example surface-conductive electron emitting device provided for the electron source of the present invention, with (a) being a plan view and (b) being a cross-sectional view.

[Fig. 8]

This is a process diagram showing the device forming processing in Fig. 7.

[Fig. 9]

This is a graph showing a voltage waveform in the electroforming process performed for the manufacture of the surface-conductive electron emitting devices of the electron source according to the present invention, with (a) showing a case wherein a pulse peak value is a constant, and (b) showing a case wherein the pulse peak value is increased.

[Fig. 10]

This is a schematic diagram showing the configuration of a measurement and evaluation apparatus for the electron emission characteristics of the surface-conductive electron emitting device.

[Fig. 11]

This is a diagram showing the current-voltage characteristic of the surface-conductive electron emitting device.

[Fig. 12]

This is a schematic diagram showing the configuration of an electron source substrate wherein multiple surface-conductive electron emitting devices are arranged by using simple matrix wiring.

[Fig. 13]

This is a schematic diagram showing the configuration of an electron source substrate whereon multiple surface-conductive electron emitting devices are arranged by using line wiring.

[Fig. 14]

This is a partially cutaway perspective view of another example configuration for the image forming apparatus according to the present invention.

[Fig. 15]

This is a schematic plan view of the device structure of an electron source substrate manufactured in a second embodiment.

[Fig. 16]

This is a process diagram showing the processing for the manufacture of the electron source substrate for the second embodiment.

[Description of the Reference Numerals and Signs]

1: insulating substrate

2: thin film for forming an electron emitting portion

3: electron emitting portion

4: thin film including electron emitting portions

5: device electrode

6: device electrode

11: device electrode

12: device electrode

13: wiring for a first layer

14: inter-layer insulating layer

14a: recessed portion

15: wiring for a second layer

16: wiring for a third layer

17: electron emitting portion

31: electron source substrate

32: rear plate

33: support frame

34: electron emitting device

35: X-directional wiring

36: Y-directional wiring

37: glass substrate

38: fluorescent film

39: metal back

40: face plate

41: outer case

42: black member

43: fluophor

90: ammeter

91: power source

92: ammeter

93: high voltage power source

94: anode electrode

111: insulating substrate

112: X-directional wiring

113: Y-directional wiring

114: surface-conductive electron emitting device

120: electron source substrate

121: surface-conductive electron emitting device

122: common wiring

130: grid electrode

131: through hole for passage of electrons

132: external case terminal

133: external case terminal

134: electron source substrate

141: device electrode

142: device electrode

143: wiring for a first layer

144: wiring for a second layer

145: electron emitting portion

146: wiring for a third layer

147: connection pattern (connection layer)

148: connection pattern (connection layer)

[Fig. 4]

high voltage terminal Hv

31: electron source substrate

32: rear plate

33: support frame

34: electron emitting device

35: x wiring

36: y wiring

37: glass substrate

38: fluorescent film

39: metal back

40: face plate

41: outer case

device electrode

[Fig. 5]

42: black member

43: fluophor

[Fig. 9]

electroforming voltage

time

electroforming voltage

time

[Fig. 10]

vacuum apparatus

[Fig. 11]

device current If

discharge current Ie

device voltage Vf

[Fig. 14]

terminal Hv

vacuum container VC

34: electron emitting device

38: fluorescent film

40: face plate

130: grid electrode

131: through hole

132: external case terminal

133: external case terminal

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[Amendment 1]

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[Amended Contents]

[Claims]

[Claim 1]

A manufacturing method, for an electron source wherein a plurality of electron emitting devices, which emit electrons by applying a voltage to paired electrodes, are located between a plurality of X-directional wiring lines, which are formed on a substrate, and a plurality of Y-directional wiring lines, which are electrically insulated from said X-directional wiring lines and are arranged substantially perpendicular to said X-directional wiring lines, and wherein one of said paired electrodes is electrically connected to one of said X-directional wiring lines, and the other device electrode is electrically connected to one of said Y-directional wiring lines, characterized by comprising the steps of:

forming a plurality of said paired electrodes on said substrate;

forming wiring for a first layer to be electrically connected to one of said paired electrodes (a

first device electrode);

forming, substantially perpendicular to said wiring for said first layer, an insulating layer in a belt shape that has a plurality of recessed portions so as to be narrowed at an intersection with said first device electrode; and

forming wiring for a third layer on said wiring for said second layer.

[Claim 2]

A manufacturing method, for an electron source, according to claim 1, whereby said wiring for said second layer and said wiring for said third layer are formed by using the same material.

[Claim 3]

A manufacturing method, for an electron source, according to claim 1 or 2, characterized by employing a printing method to form said insulating layer, said wiring for said second layer and said wiring for said third layer.

[Claim 4]

A manufacturing method, for an electron source, according to one of claims 1 to 3, further comprising the steps of:

forming a conductive thin film for connecting said paired electrodes; and

performing an electrification process for said conductive thin film to form an electron emitting portion on one part of said conductive thin film.

[Claim 5]

A manufacturing method, for an electron source wherein a plurality of electron emitting devices, which emit electrons by applying a voltage to paired electrodes, are arranged between two adjacent wiring lines, out of a plurality of wiring lines that are located on a substrate substantially in one direction, and wherein one of said paired electrodes is connected to one of said two adjacent wiring lines while the other device electrode is connected to the other adjacent wiring line, comprising the steps of:

forming a plurality of said paired electrodes on said substrate;

forming wiring for a first layer that includes a first connection layer to be electrically connected to one of said paired electrodes (first device electrode);

forming wiring for a second layer, parallel to said wiring for said first layer, with said paired device electrodes in between;

forming a second connection layer to connect the other device electrode (second device electrode) to said second wiring; and

forming wiring for a third layer on said wiring for said second layer, or on said wiring for said second layer and said second connection layer.

[Claim 6]

A manufacturing method, for an electron source, according to claim 5, whereby said wiring for said second

layer and said wiring for said third layer are formed by using the same material.

[Claim 7]

A manufacturing method, for an electron source, according to claim 5 or 6, whereby said wiring for said first layer and said second connection layer are formed at the same time.

[Claim 8]

A manufacturing method, for an electron source, according to one of claims 1 to 7, whereby said wiring for said second layer and said second connection layer are formed at the same time.

[Claim 9]

A manufacturing method, for an electron source, according to one of claims 5 to 8, characterized by employing a printing method to form said wiring for said second layer and said wiring for said third layer.

[Claim 10]

A manufacturing method, for an electron source, according to claim 9, characterized by employing a printing method to form said second connection layer, said wiring for said second layer and said wiring for said third layer.

[Claim 11]

A manufacturing method, for an electron source, according to one of claims 5 to 11, further comprising a step of:

performing an electrification process for said

conductive thin film to form an electron emitting portion on a part of said conductive thin film.

[Claim 12]

A manufacturing method, for an image forming apparatus, comprising the steps of:

manufacturing an electron source substrate by using a method according to one of claims 1 to 4;

bonding, through a support frame, said obtained electron source substrate and a substrate including a fluorescent film, while said substrates face each other; and

reducing pressure in a space defined between said two substrates.

[Claim 13]

A manufacturing method, for an image forming apparatus, comprising the steps of:

manufacturing an electron source substrate by using a method according to one of claims 5 to 11;

locating, opposite each other, said obtained electron source substrate and a substrate having a fluorescent film, and bonding said two substrates through a support frame, while a plurality of grid electrodes are arranged between said two substrates; and

reducing pressure in a space defined between said two substrates.

[Claim 14]

An electron source obtained by a manufacturing

method according to one of claims 1 to 11.

[Claim 15]

An image forming apparatus obtained by a manufacturing method according to claim 12 or 13.

[Amendment 2]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] 0014

[Amendment Type] Replace

[Amended Contents]

[0014]

The present invention relates to a manufacturing method, for an electron source wherein a plurality of electron emitting devices, which emit electrons by applying a voltage to paired electrodes, are located between a plurality of X-directional wiring lines, which are formed on a substrate, and a plurality of Y-directional wiring lines, which are electrically insulated from the X-directional wiring lines and are arranged substantially perpendicular to the X-directional wiring lines, and wherein one of the paired electrodes is electrically connected to one of the X-directional wiring lines, and the other device electrode is electrically connected to one of the Y-directional wiring lines, characterized by comprising the steps of:

forming a plurality of the paired electrodes on the substrate;

forming wiring for a first layer to be electrically connected to one of the paired electrodes (a first device electrode);

forming, substantially perpendicular to the wiring for the first layer, an insulating layer in a belt shape that has a plurality of recessed portions so as to be narrowed at an intersection with the first device electrode; and

forming wiring for a third layer on the wiring for the second layer.

[Amendment 3]

[Name of Document to be Amended] Specification

[Name of Item to be Amended] 0015

[Amendment Type] Replace

[Amended Contents]

[0015]

Further, the present invention relates to a manufacturing method, for an electron source wherein a plurality of electron emitting devices, which emit electrons by applying a voltage to paired electrodes, are arranged between two adjacent wiring lines, out of a plurality of wiring lines that are located on a substrate substantially in one direction, and wherein one of the paired electrodes is connected to one of the two adjacent wiring lines while the other device electrode is connected to the other adjacent wiring line, comprising the steps of:

forming a plurality of the paired electrodes on the substrate;

forming wiring for a first layer that includes a first connection layer to be electrically connected to one of the paired electrodes (first device electrode);

forming wiring for a second layer, parallel to the wiring for the first layer, with the paired device electrodes in between;

forming a second connection layer to connect the other device electrode (second device electrode) to the second wiring; and

forming wiring for a third layer on the wiring for the second layer, or on the wiring for the second layer and the second connection layer.